

# NASA TECH BRIEF



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## Bell Nozzle Kernel Analysis Program

### The problem:

To develop a means for computing and analyzing the supersonic flowfield in the kernel, or initial expansion region, of a bell or conical nozzle.

### The solution:

The Bell Nozzle Kernel Analysis Program meets this demand and analyzes both plane and axisymmetric geometries for specified gas properties, nozzle throat geometry and input line.

### How it's done:

The program computes the supersonic flowfield in the kernel or initial expansion section of an axisymmetric or plane bell or conical nozzle. The flowfield bounded by the supersonic input or starting line, the circular arc initial expansion section, right-running characteristic line extending to the axis, and the axis of symmetry, are computed for either an ideal gas with a constant specific heat ratio or for a reacting gas composition (frozen or shifting equilibrium). Right characteristics are used in the design or analysis of bell nozzle overturning sections. Use of kernel input lines rather than throat input lines in the analysis of bell nozzle allows considerable reductions in computer time when several cases are to be run, or when the length and expansion area ratio of the nozzle overturning section are sufficiently large to overflow the bell analysis program's limited storage capacity.

The program uses the method-of-characteristics for steady, irrotational, supersonic flow, and computes the nozzle throat wall pressure profile, thrust coefficient and flow properties of right-running characteristic lines extending from the nozzle throat to the axis of

symmetry. The method-of-characteristics refers to a method for the solution of a set of hyperbolic partial differential equations. In steady supersonic, axisymmetric or plane flow, the vector equations may be written which express continuity of flow, the potential energy of flow, and irrotationality of flow. These vector equations may be expanded to a set of hyperbolic partial differential equations describing the flow in the supersonic flowfield. Using the method-of-characteristics, these partial differential equations can be further reduced to yield the total differential equations for the characteristic surfaces throughout the flowfield. This method for determining the flow properties of a compressible gas flowing at supersonic velocity is valid only if strong shock waves do not exist, although the results are useful for the case of weak compression waves. Weak compression waves are usually present in the flow of a contoured or bell nozzle.

### Notes:

1. The documentation assumes that the user has a prior knowledge of the method-of-characteristics, and it makes reference to two sources for a detailed development of the characteristic equations.
2. This program was written in FORTRAN H language for use on the IBM 360 computer.
3. Inquiries concerning this innovation may be directed to:

COSMIC  
Computer Center  
University of Georgia  
Athens, Georgia 30601  
Reference: B69-10146

(continued overleaf)

**Patent status:**

No patent action is contemplated by NASA:

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